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History of forests in the Glacial Lake Chicago area

G. K. Guennel

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The *Butler University Botanical Studies* journal was published by the Botany Department of Butler University, Indianapolis, Indiana, from 1929 to 1964. The scientific journal featured original papers primarily on plant ecology, taxonomy, and microbiology. The papers contain valuable historical studies, especially floristic surveys that document Indiana's vegetation in past decades. Authors were Butler faculty, current and former master's degree students and undergraduates, and other Indiana botanists. The journal was started by Stanley Cain, noted conservation biologist, and edited through most of its years of production by Ray C. Friesner, Butler's first botanist and founder of the department in 1919. The journal was distributed to learned societies and libraries through exchange.

During the years of the journal's publication, the Butler University Botany Department had an active program of research and student training. 201 bachelor's degrees and 75 master's degrees in Botany were conferred during this period. Thirty-five of these graduates went on to earn doctorates at other institutions.

The Botany Department attracted many notable faculty members and students. Distinguished faculty, in addition to Cain and Friesner , included John E. Potzger, a forest ecologist and palynologist, Willard Nelson Clute, co-founder of the American Fern Society, Marion T. Hall, former director of the Morton Arboretum, C. Mervin Palmer, Rex Webster, and John Pelton. Some of the former undergraduate and master's students who made active contributions to the fields of botany and ecology include Dwight. W. Billings, Fay Kenoyer Daily, William A. Daily, Rexford Daudenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daubenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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HISTORY OF FORESTS IN THE GLACIAL LAKE CHICAGO AREA[1]

By G. K. GUENNEL

By means of pollen studies it has been possible at least to venture estimates of the ecological conditions which existed and developed during post-glacial periods. Climate is no doubt the most important factor in determining the extensive formations of vegetations and their replacements. Weaver and Clements (20) state: "Climate may produce new areas for succession through the destruction of existing vegetation." If this be true, then the pollen analyst can estimate, on the basis of forest types as indicated by fossil pollen findings, what climatic conditions prevailed over wide geographic areas, since the forest types would be directly dependent on the climate, making the two synonymous within greater or lesser degree. While to date 22 Indiana bogs have been studied in detail, the overall picture of climatic and vegetational changes within the state is still somewhat incomplete. As new discoveries are being added to the present store, the picture of past vegetation evolves more clearly, and this in turn gives an estimate of the climatic conditions which prevailed since the retreat of the continental ice sheets which once covered much of Indiana.

Indiana is of special interest, as well as importance, in this respect, since it has glaciated as well as unglaciated topography and so involves important border areas. According to Malott (10) there is a driftless or unglaciated triangle in south-central Indiana. Three major glacial periods are recognized in Indiana, viz., the Illinoian, the Early and the Late Wisconsin. Since neither of the successively later ice sheets extended as far southward as its predecessor, we have exposed in the state a wide belt of each of these periods. Unfortunately no bogs have been found to date on the Illinoian till plain. The border line between the Illinoian and Early Wisconsin glaciations runs from Vigo county in the west to Franklin county in the east. The border of the Late Wisconsin sub-stage extends from Benton county on the western border to Randolph county in the east.

[1] A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Science degree in the Division of Graduate Instruction, Butler University.

Friesner (3), in correlating the glaciations with the effects they had on plant life, states: "These alternate southward and northward movements of ice and plants probably occurred many times in eastern North America. Indiana was a critical area for this plant-climate struggle because the edges of maximum extension of each of the last two ice sheets (Illinoian and Wisconsin) are to be found within her borders."

The pollen profiles of Pinhook and Merrillville bogs presented in this paper, represent a further contribution to the history of plant successions since the recession of the ice sheets. Both bogs are found within the boundary of the Late Wisconsin ice sheet. Pinhook bog is located west of La Porte in La Porte county, while Merrillville bog is in Lake county, north of Crown Point.

Glacial Lake Chicago, the ancestor of Lake Michigan, extended slightly farther south than the present shore line and was apparently bound in by the Valparaiso moraine which extends across Lake, Porter, and La Porte counties.

METHODS

The peat samples from Pinhook bog were collected in the fall of 1940 and those from the Merrillville bog in March 1948. Several trial borings were made in each bog in order to be certain that the deepest part of the basin was being sampled and thus assure getting a complete profile (Potzger, 12). Samples were taken at every foot-level, including the surface layer except at several foot-levels in the Pinhook bog where no samples were obtainable due to the fluid or gelatinous nature of the sediments. In the Merrillville bog samples were taken at closer intervals at a few critical levels.

The peat samples were prepared for study according to both the alkali and the alcohol method (Geisler, 4). The former proved better for certain badly dried-out samples. Slight modifications were made in following the two techniques. In order to minimize damage to the rather delicate fossil grains, only the first step of the KOH method was employed, that is, no centrifuging or decanting was undertaken. Also, instead of applying glycerin after boiling in KOH, pre-stained glycerin jelly was used. This process of using pre-stained jelly is also a slight deviation from the Geisler method. Instead of staining the material for each given foot-level with gentian violet, the glycerin jelly was stained, thus eliminating one step in preparing the material for study.

Publications by Sears (17), Erdtmann (2), Wodehouse (21), and Wilson and Webster (20), together with slides prepared from known pollens of present-day species, were used to verify classification of fossil grains. The final word, however, on any questionable grain was given by Dr. Potzger. Two hundred tree pollens were counted at each foot-level, except at the surface and at the 27-foot level of the Pinhook boring. Because of the extreme scarcity of pollen, only 100 and 160 respectively were counted at those levels. Forty slides had to be prepared before the 160 pollen grains of tree species were obtained at the 27-foot level. A similar difficulty was encountered in the Merrillville boring. The lowermost three levels (34.5, 34, and 33.25 feet) yielded so little pollen that the first- and last-mentioned levels were omitted from the profile. At the 34-foot level 50 grains were counted. The sediments representing these three samplings were sandy marl, but the next sample, at the 33-foot level, was pure marl and yielded sufficient pollen for complete counts. Less than 200 pollen grains were counted at the following foot-levels: 34 (50); 10 (100); 8 (100); 6 (115); 5 (75); 4 (100); 3 (100); 2 (100); 1 (100) and 0.25 (50). The 2.5- and 1.5-foot levels were also omitted in the graphs because of the small number of tree pollens present in the sediments. Erdtmann (2) and Sears (17), as well as Potzger (12), advocate counting 200 grains. Barkley (1) says: "There is little significant shifting of relative percentage beyond the 200 count."

Shrub and herb pollens, as well as spores of pteridophytes and mosses were tabulated but not included in the graphs and tables. Tetrads and clusters of grains which came from the same anther, as evidenced by anther remains, were counted as one grain only. Two magnifications were used in the examination of the slides, 150x for locating the grains, and 645x for measuring and identification. A binocular monobjective type of microscope with mechanical stage was used.

SPECIATION

No difficulty was encountered in distinguishing the three main genera possessing wing-type pollen, namely Abies, Picea, and Pinus. The outstanding features enabling differentiation were size and "re-entrant" angle of the wings. The latter feature sets off the spruces from the other two. Pollen grains of Picea have no distinct

angle at the point where the bladders meet the tube cell, while in Abies and Pinus pollen a sharp angle is formed at that point (fig. 2). In size-range there is an overlapping between Abies and *Picea glauca,* the largest spruce grain. Abies grains ranged from 90 to 115.2 microns, with the average at 104.7, and *Picea glauca,* with an average of 98.28, ranged from 92.4 to 104.4. When wings are present (some

Fig. 1

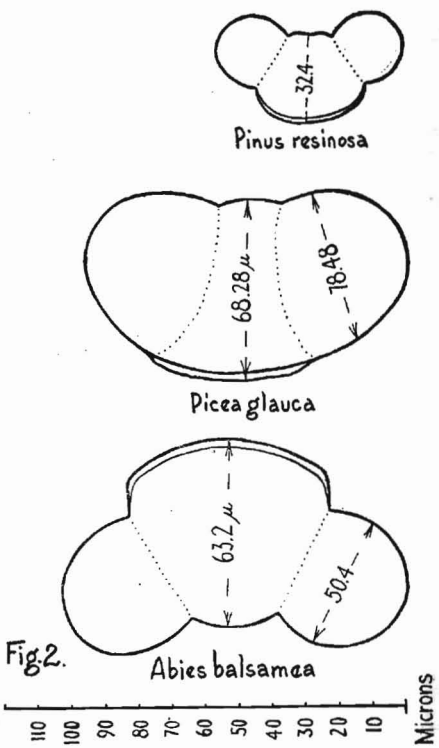


Fig. 2.

fossil grains are broken or crushed) the two types of pollen can be differentiated readily. Abies wings measured from 36 to 57.6 microns, whereas *Picea glauca* wings showed a range of 60 to 78. The modes for size of the wings are 75 microns for *P. glauca* and 45 for Abies, with average of 78.48 and 50.4 respectively. The measurements of the wings were taken parallel to the lines of attachment, at

the greatest diameter (fig. 2). A similar situation was encountered in differentiating the smaller spruce, *Picea mariana,* from the larger pines, since the sizes overlap. Again, the re-entrant angle usually sufficed as means of distinguishing, since pine pollen is similar in shape to that of Abies.

The real difficulty was met when attempting to differentiate Pinus pollen on the basis of size. That there are differences in size was apparent, but the grains of the various species seem to overlap to such an extent that it was practically impossible to determine the species definitely, at least in the overlapping size ranges. After a brief study of modern pollen from eight species of pines, the author risked classifying the fossil grains into *Pinus strobus* and *Pinus banksiana*: grains above 60 microns in overall size were termed *P. strobus,* and the grains measuring under 60 were classified as *P. banksiana.*

RESULTS

Pinhook Bog

Results from study of the Pinhook bog are shown in table 1 and fig. 3. A graphic presentation of the main forest types, as indicated by pollen frequency, is given in fig. 4. The percentage figures include only tree pollens, since the study concerned itself primarily with forest succession.

The Pinhook profile shows a strong Abies-Picea association in the lower foot-levels. At the 54-foot level *Picea glauca* and *P. mariana* combined constitute 81% of all the tree pollen. Abies appears to have been definitely associated with Picea, as evidenced by the simultaneous decline of the two genera. After dominating the profile for about one-third of its depth, Picea, with the exception of several brief gains, never again attains a dominating position. Abies is completely lacking above the 34-foot level.

Although Pinus is present from the beginning it shows no dominance until after the fir-spruce decline. Following a peak at the 39- and 38-foot levels, *Pinus banksiana* gives way to *Pinus strobus.* The latter reaches its peak at the 36-foot level. At the 34-foot level both pines decline rather abruptly, never to exceed 12% of the tree pollen total at any succeeding level.

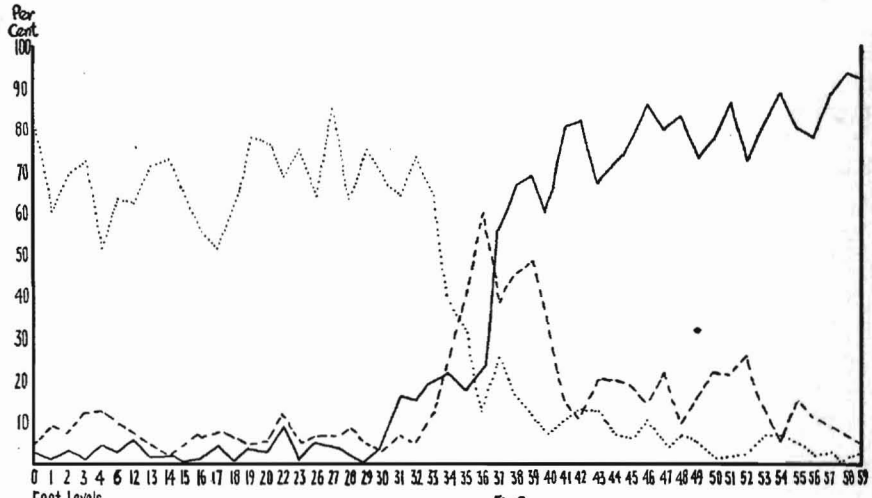


Fig. 4. PINHOOK BOG

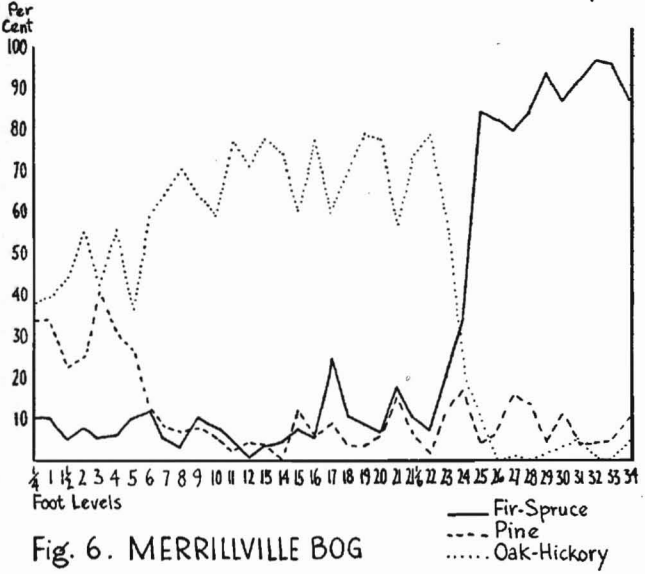


Fig. 6. MERRILLVILLE BOG

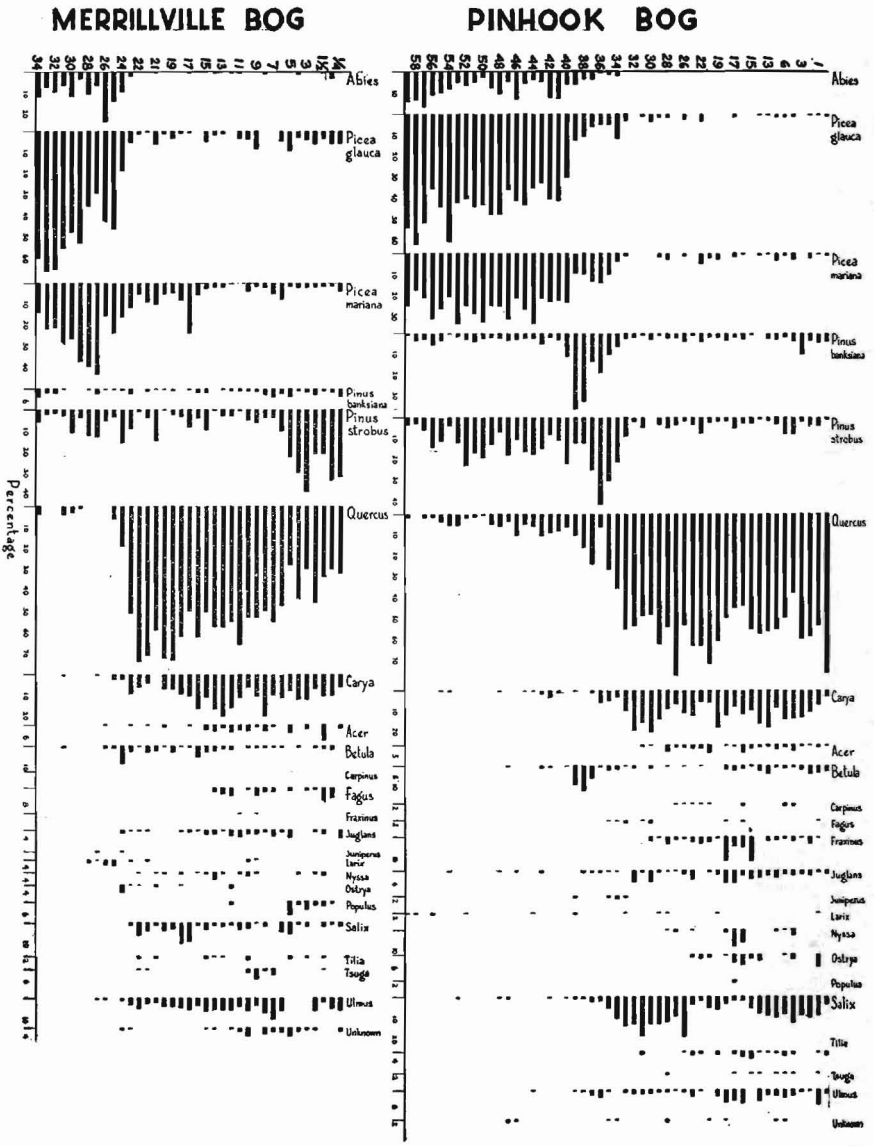
With the decline of Pinus, Quercus increases in dominance. While oak pollen in small quantities was present even in the samples from the lowest levels, it contributed most pollen from the 35-foot level upward, reaching a maximum of 78% at the 27-foot level. Carya made several appearances throughout the Picea-Pinus period, but it first becomes conspicuous as an associate of Quercus from the 33-foot level upward. Of the other genera represented, only Betula and Salix show more than 10% representation. The latter attained a peak of 17.5% at the 31-foot level and Betula showed 12% at the 38-foot level.

Merrillville Bog

Results from study of the Merrillville bog are shown in table II and fig. 5. The succession of the main forest types or associations is shown in fig. 6. The lowermost layers of the Merrillville bog contained only pollen of Abies, Picea and Pinus. The first-mentioned genus attains a maximum representation of 23.5% at the 26-foot level and nearly disappears after the 23-foot level. *Picea glauca* starts with 62.5% at the 34-foot level, drops to 28.5% at the 27-foot level, and after attaining 45.5% at the 25-foot level declines abruptly at the 23-foot level. At the 27-foot level *P. mariana* attains its peak (43%), making up for the drop in *P. glauca* at that level. Both spruces participate in the spectrum to the surface, but do not make any serious advances toward dominance.

Pinus strobus was present at every foot-level. In the lower half of the bog it reaches its maximum at the 24-foot level with a frequency of 16%, while near the surface it rises to real prominence, at two foot-levels even exceeding Quercus. Its maximum representation (39%) is attained at the 3-foot level. *Pinus banksiana* never gains great abundance even though it was present throughout the profile.

In the lower third of the profile, Quercus appears in very small percentages but at the 24-foot level it first shows signs of importance with 19% representation. At the next higher foot-level it increased to 49%, while at the 20- and 19-foot levels it attains its peak of 70.5 and 71.5% respectively. It remains prominent throughout the upper layers and from the 5-foot level on it meets competition from *Pinus strobus,* which actually outnumbers it at the 3- and 1-foot levels.


MERRILLVILLE BOG
PINHOOK BOG
Percentage
Abies
Picea glauca
Picea mariana
Pinus banksiana
Pinus strobus
Quercus
Carya
Acer
Betula
Carpinus
Fagus
Fraxinus
Juglans
Juniperus
Larix
Nyssa
Ostrya
Populus
Salix
Tilia
Tsuga
Ulmus
Unknown

Here, as in the Pinhook bog, Carya does not reach a high percentage of representation but becomes an important associate of oak. None of the other genera recorded in the spectrum display great importance from the standpoint of numerical representation.

DISCUSSION.

Despite its limitations, pollen analysis is a valuable aid to reconstruction of vegetations as they occurred in post-glacial time. The spectra of the two bogs studied show that the forest type of northern Indiana, immediately following glaciation, resembled closely the boreal or northern forest of today. When one considers that the lower deposits represent 400 to 500 years in time per foot-level (Potzger and Wilson, 16), it is understandable that considerable change in forest composition due to local fluctuations and conditions could have taken place, which in turn fostered, or at least permitted changes in generic representation in the associations. The danger of correlating slight increases or decreases in frequency of a certain pollen type with a major climatic change is ever-present when interpreting fossil pollen findings. We should, perhaps, make interpretation lean more heavily on ecological surveys of present-day vegetation. Potzger (13) in such a correlation study in central northern Wisconsin and upper Michigan, discusses microclimatic and edaphic factors as influences in determining forest covers. Potzger and Friesner (15), in studying present-day vegetations in central Indiana, found a mixed mesophytic forest (Acer-Fagus dominance) on north-facing slopes, while the south-facing slopes were vegetated by a typical oak-hickory forest type. The ridges terminating the slopes represent only slight distances, and the slopes in question are within the same climatic range or belt. Such forest distribution phenomena show that macroclimate is not the only factor which determines and controls plant associations. Potzger (14) breaks down microclimate into various constituent influences, such as evaporation, temperature, moisture, and edaphic relations.

The northern forest, as indicated by Picea and Abies, declined suddenly in both profiles. This is a characteristic but baffling phenomenon in the Lake States region, as pointed out by Potzger (13). This abrupt decline of fir-spruce is coupled with an equally sudden rise of pine in the Pinhook profile. In the Merrillville record the transition is more direct to a deciduous forest type, namely to an oak-hickory

association. The sudden decline of the boreal forest agrees with previous findings in Late Wisconsin bogs of northern Indiana. Keller (7) reported abrupt changes from Abies-Picea to Pinus for Jeff, Culver, and Shipshewana bogs in Wells, Starke, and La Grange counties, Indiana, and Smith (18), as well as Howell (6) found the same behavior of these boreal genera in the profiles of Lake Cicott and Kokomo bogs. Moss (11) reported a similar sudden transition in Silver Lake bog (Kosciusko county) and Altona bog (De Kalb county), while in Round Lake bog (Starke county) Hamp (5) found a direct transition from Abies-Picea to oak as in the Merrillville profile.

In the light of the uniformity of persistence and decline of spruce-fir forests in a number of northern Indiana bog profiles, it can he assumed that the climate immediately following glacial recession was cold and moist. That climate is directly responsible for forest climax changes, although not the sole factor, is further proven when sudden changes occur between two widely diverse forest types (coniferous and deciduous). The Pinhook records show just such a sudden transition. After pine dominated during a period in which five foot-levels of peat accumulated, Quercus increased greatly resulting in an equally sudden drop of pine (figs. 3 and 4). Moss (11) says: "In all Indiana bogs the transition from a coniferous to a deciduous forest is sudden, i.e., within the range of one foot-level." This occurred in the Pinhook spectrum at the 34- and 33-foot levels. The Merrillville profile shows an even more pronounced transition from a boreal type of forest to an oak-hickory association. At the 25-foot level the conifers Abies, Picea, and Pinus combined totaled 87.5%, and oak and hickory only 8.5%. At the 23-foot level a reversal is evident in that oak and hickory here contributed almost twice as much pollen as the conifers. Lindsey (9), in his preliminary study of Merrillville bog, showed the same abrupt transition from coniferous to deciduous forest. This change indicates that the climate became warmer and drier favoring a Quercus-Carya climax. The Merrillville bog record, in its lack of a pronounced pine dominance, differs from that of the Pinhook and all other Late Wisconsin bogs investigated in Indiana, except the one at Round Lake studied by Hamp (5).

The present study shows that care must be exercised in the interpretation of climatic factors from pollen profile data of single areas. The two bogs are located within the same latitude and they are sepa-

rated by only 25 miles in an east-west direction, yet there are forest differences which might indicate major climatic differences between the two places. This reminds one forcefully that variation (microclimatic) in environmental control of forest types must find a place in interpretation of pollen profiles. The Merrillville area did not experience the pronounced pine period which is so evident in the Pinhook profile, and constitutes a characteristic feature of Indiana bogs located in Late Wisconsin territory. If we disregard microclimatic control in our interpretation of the climate-vegetation complex at the two locations in question, we would conclude that the transition pine period, so evident at Pinhook, represents a slower climatic change, i.e., the cold and moist climate favoring Abies and Picea, first changed to a cool stage, permitting pine to express itself in proportions of dominance, whereas at Merrillville the pine transition was wanting, indicating a sudden change from cold-moist to a drier, warmer climate. Such an assumption is, of course, absurd. If macroclimate is too encompassing to account for such local differences, then microclimatic factors must be assumed in control. We use such procedure in ecological surveys of forests of today.

Oak is definitely the most important genus in both profiles, both in its own right and in combination with other genera in various associations. In the Pinhook profile one could almost speak of a transitional oak-pine period, as indicated by the pollen representation in the 37- to the 34-foot level inclusive. A similar oak-pine complex was noted in the Merrillville bog at the 24- and 23-foot levels.

The Quercus dominance in Pinhook shows Carya as a strong associate. The high percentage of Salix pollen no doubt indicates shallowing water in depressions rather than changes in either climate or the climax forest. Carya and Salix, as well as the total associated genera, could hardly be considered serious competitors of oak. A percentage decrease of Quercus and Carya, while the 18- to 13-foot levels were being deposited, is due to invasion by such genera as Ulmus, Fraxinus, Juglans, Nyssa, and Tilia, none of which ever really competed with oak on sandy uplands. This increase may be interpreted (although minor oscillations and fluctuations should not be taken too critically) as indicating a moderating climate, for as Smith (18) says: "While Ulmus, Juglans and Populus indicate moderating climate, they only represent a transitional complex of the deciduous forest, a gradual filling in of wet lowlands." Disregard-

ing minor intrusions by mesophytic genera and the prominent increase of *Pinus strobus* due to relic colony development, an oak-hickory association represents the climax forest at both locations.

The general successional trend of Merrillville bog follows closely that of Pinhook, except for a striking rise of white pine in the upper foot-levels. This rise, however, serves to illustrate further that fossil pollen findings, i.e., fluctuations of frequencies, do not necessarily always indicate major climatic changes. White pine dominance recorded at two-foot levels and close competition with oak in the other upper levels, would certainly seem to indicate a definite change in climate. Since, however, it is known that Merrillville bog was covered with a stand of *Pinus strobus* up to a few years ago, the climatic factor has to be disregarded.

After having made quadrat studies of the vegetational cover of Merrillville bog, Lindsey (8) found that *Pinus strobus* showed a 100% frequency in all 25 of the 10-meter quadrats surveyed. He states: "*Pinus strobus* is the important tree at present, but is doomed to yield its position to the incoming oaks. A pine seedling is rarely found on the forest floor, while oak seedlings are common, thus indicating that the pines are yieldng to an oak succession."

Pinus strobus persisted as an unusual relic colony until about 1940 when a fire eliminated all but one small tree. The pollen profile (fig. 3 and table 1) shows a dual dominance of oak and pine in the most recently deposited peat layers. The deposits of oak pollen grains apparently were contributed by the trees surrounding the bog proper, while the white pine pollen was deposited by the stand on the bog mat. If we merely consider fossil pollen frequency it is easily seen how climatic misinterpretations could result. It certainly could not be discounted that the abundance of pine pollen indicates a more or less proportional index of actual tree abundance, but equally certainly it would be erroneous to consider the Merrillville region as having borne a climax of pine and oak. On the basis of Lindsey's findings, it can be stated that *Pinus strobus* was not a participant in the overall climax forest of northern Indiana, or even in the region immediatley adjacent to and surrounding Merrillville bog, but that it was restricted to the bog mat itself.

These very unusual records are especially a fine recommendation for the reliability of pollen profiles in revealing the character of the forest of the area. They are at the same time highly dramatic

records. They show that centuries ago white pine multiplied and expanded into the gradually solidifying bog mat. We saw the culmination of this conquest favored by microclimate, viz., a magnificent stand of pines. The closing chapter was cruel, swift and final. A grass fire extended its destruction into the bog, and in the span of minutes the activity which had continued for centuries stopped short. There remains today on the Merrillville bog mat one lone tree.

SUMMARY

1. Pollen studies of Pinhook and Merrillville bogs, located in La Porte and Lake counties, respectively, in northern Indiana are presented in this paper.

2. Forest succession, as indicated by the Pinhook profile, was: Picea-Abies to Pinus to Pinus-Quercus to Quercus-Carya.

3. At Merrillville the succession was: Picea-Abies to Pinus-Quercus to Quercus-Carya to Pinus-Quercus-Carya. The mid-profile Pinus period was wanting.

4. An increase of white pine pollen in the upper levels of the Merrillville profile was due to local (microclimatic) rather than climatic factors.

5. The following climatic changes can be assumed on basis of the two spectra: cold-moist to a cool-drier terminated by a warm-dry climate.

6. Special data bearing upon the reliability of pollen profiles are presented. The pollen record in the topmost layers of Merrillville bog is certified by a recent ecological survey.

ACKNOWLEDGMENTS

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LITERATURE CITED

1. Barkley, Frederick A. The statistical theory of pollen analysis. Ecology 15:283-289. 1934.
2. Erdtmann, G. An introduction to pollen analysis. Chroniea Botanica Co. 1943.
3. Friesner, Ray C. Indiana as a critical botanical area. Indiana Acad. Sci. Proc. 46:28-45. 1937.
4. Geisler, Florence. A new method of separation of fossil pollen from peat. Butler Univ. Bot. Stud. 3:141-146. 1935.
5. Hamp, Frank A. A fossil pollen study of two northern Indiana bogs. Butler Univ. Bot. Stud. 4:217-225. 1940.
6. Howell, John A. A fossil pollen study of Kokomo bog, Howard county, Indiana. Butler Univ. Bot. Stud. 4:117-127. 1938.
7. Keller, Carl O. A comparative study of three Indiana bogs. Butler Univ. Bot. Stud. 6:65-80. 1943.
8. Lindsey, Alva J. The Merrillville White Pine (*Pinus strobus*) bog, Lake county, Indiana. Butler Univ. Bot. Stud. 2:167-178. 1932.
9. Lindsey, Alva J. Preliminary fossil pollen analysis of the Merrillville White Pine bog. Butler Univ. Bot. Stud. 2:179-182. 1932.
10. Malott, Clyde A. The physiography of Indiana. Handbook of Indiana Geology. Dept. of Conservation. Publication No. 21. 1922.
11. Moss, Byron W. A comparative pollen analysis of two bogs within the boundaries of the Late Wisconsin glaciation in Indiana. Butler Univ. Bot. Stud. 4:207-216. 1940.
12. Potzger, John E. Pollen study of five bogs in Price and Sawyer counties, Wisconsin. Butler Univ. Bot. Stud. 6:54-64. 1943.
13. ———. Phytosociology of the primeval forest in central-northern Wisconsin and upper Michigan, and a brief post-glacial history of the Lake Forest formation. Ecol. Monog. 16:211-250. 1946.
14. ———. Microclimate and a notable case of its influence on a ridge in central Indiana. Ecology 20:29-37. 1939.
15. ——— and Ray C. Friesner. What is climax in central Indiana? A five-mile quadrat study. Butler Univ. Bot. Stud. 4:181-195. 1937.
16. Potzger, John E. and Ira T. Wilson. Post-pleistocene forest migration as indicated by sediments from three deep inland lakes. Amer. Midland Nat. 25:270-289. 1941.
17. Sears, Paul B. Common fossil pollen of the Erie basin. Bot. Gaz. 87:95-106. 1930.
18. Smith, William M. Pollen spectrum of Lake Cicott bog, Cass county, Indiana. Butler Univ. Bot. Stud. 4:43-54. 1937.
19. Weaver, John E. and Frederick E. Clements. Plant Ecology. McGraw-Hill Book Co. 1938.
20. Wilson, L. R. and R. M. Webster. Microfossil studies of three north central Wisconsin bogs. Wisconsin Acad. Sci. Arts and Letters 34:177-193. 1942.
21. Wodehouse, R. P. Pollen grains. McGraw-Hill Book Co. 1935.

TABLE I

Percentages of tree pollens—Pinhook bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
0	0.	1.	3.	0.	3.	0.	0.	2.	0.	0.	0.	0.	1.	1.	4.	1.	0.	76.	4.	2.	0.	2.	0.
1	0.	1.5	3.5	0.	7.	0.5	0.5	1.	0.	0.5	0.	6.	0.5	0.5	4.5	4.	0.	53.	9.	0.5	0.5	7.	0.
2	0.	0.5	4.	0.	10.5	0.	3.5	2.5	0.	0.	0.	0.	0.5	2.5	3.5	3.5	0.	58.5	10.	0.	0.	0.5	0.
3	0.	1.	2.	0.	13.	0.	0.5	0.	0.	0.	0.	0.	0.	0.	10.	2.	0.	59.5	9.	0.	0.	1.	0.
4	0.	3.	1.	1.5	13.5	0.	2.	2.5	0.	0.	3.	2.5	1.	3.	4.	8.	0.	37.5	12.5	1.5	0.5	3.	0.
6	0.	1.5	1.5	1.5	14.	0.	1.	2.	0.	0.	0.5	0.5	1.5	1.	2.	8.	0.	49.5	8.5	2.	0.5	3.5	1.
12	0.	2.5	1.	0.	8.5	0.	1.5	3.5	0.	0.	1.	0.	1.5	3.5	3.	3.5	0.	55.	10.	1.	0.5	3.	1.
13	0.	1.	4.	0.	17.5	0.	2.	2.5	0.	0.	0.	0.	0.5	0.5	2.5	1.5	0.	56.	9.	0.5	0.	2.5	0.
14	0.	1.5	2.5	0.	16.	0.	0.	3.5	0.	0.	0.	3.	0.5	1.	0.	1.	0.	57.	8.	0.5	0.5	5.	0.
15	0.	2.	0.5	0.	9.5	0.	11.5	4.	0.	0.	0.	4.	0.	0.	1.	3.	0.	55.	5.5	3.5	0.5	0.	0.
16	0.	4.	1.5	1.5	11.5	1.	5.	2.5	0.	0.	6.5	5.	0.	0.5	3.	3.	0.	44.	2.	2.5	0.	6.5	0.
17	0.	1.	2.5	0.	8.	0.	4.5	6.	0.	0.	8.	4.	1.5	2.	2.	5.	1.5	45.	2.	1.5	0.5	5.	0.
18	0.	0.5	2.	0.	12.	0.5	11.5	6.	0.	0.	1.5	0.5	0.	0.	3.5	2.	0.	49.5	3.5	0.	0.	6.	0.
19	0.	0.	0.	0.	18.	0.	1.	2.	0.	0.5	0.	0.	0.	3.	2.	2.	0.	60.5	6.5	1.5	0.	3.	0.
20	0.	4.	0.	0.5	6.	0.	2.5	1.	0.	0.	0.	1.5	0.	2.5	2.	2.5	0.	71.5	5.5	0.	0.	0.	0.5
22	0.	2.	0.5	0.5	5.5	0.	3.	0.	0.	0.	0.	2.	3.5	5.	4.	7.5	0.	63.	2.	1.	0.	0.5	0.
23	0.	2.	0.	0.5	12.5	0.	2.5	4.5	0.	0.	0.5	1.5	0.	0.	1.	3.5	0.	63.	4.	1.5	0.	3.	0.
26	0.	1.5	0.5	0.5	11.	0.	1.	2.	0.	0.	0.	0.	2.5	1.5	4.	2.	0.	53.	19.	0.5	0.	1.	0.
27	0.	1.25	0.	0.6	6.8	0.	1.25	0.6	0.	0.	1.25	0.	0.	0.	2.5	3.75	0.	71.25	10.	0.	0.	0.6	0.

TABLE I—(Continued)

Percentages of tree pollens—Pinhook bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
28	0.	3.5	0.5	0.	9.	0.	3.5	0.5	0.	0.5	0.5	0.	1.5	3.	2.5	5.	0.	54.	12.	0.	1.	1.	1.5
29	0.	0.	0.	0.	14.	0.	0.5	1.	0.	0.5	0.	0.	1.5	2.	1.	3.5	0.	62.	13.	0.	0.	1.	0.
30	0.	0.5	1.5	0.	20.	1.5	2.	5.5	0.	0.	0.	0.	3.5	0.	3.	0.	0.	48.	13.	0.	0.	1.5	0.
31	0.	1.	0.	0.	15.5	5.	0.	1.	0.	0.	0.	0.	1.	0.	1.	5.	0.	48.5	18.5	1.5	0.	2.	0.
32	0.	1.	1.5	0.	19.5	0.	0.	5.5	0.	0.	0.	0.	0.	0.	2.	2.	0.	53.5	13.5	0.	0.5	2.	0.
33	0.	0.	0.5	0.	10.	1.5	0.	0.	1.	0.5	0.	0.	3.	1.5	2.5	9.	0.	55.	14.	0.	0.	1.5	0.
34	2.	0.	2.	0.	3.5	0.5	0.	0.5	1.5	0.	0.	0.	11.5	4.	6.5	21.5	0.	35.5	10.5	0.	0.	0.	0.5
35	1.5	0.	2.5	0.	5.	0.5	0.	0.5	1.	0.	0.	0.	5.	10.	10.	30.5	0.	26.5	5.5	0.	0.	1.	0.5
36	0.5	0.	1.	0.	6.	0.	0.	1.	0.	0.	0.	0.	5.	14.	19.	41.5	0.	6.5	2.	0.	0.	3.5	0.
37	3.5	0.5	6.5	0.	1.5	0.	0.	1.	0.	0.	0.	0.	6.	13.5	13.5	25.	0.	24.	2.5	0.	0.	2.5	0.
38	3.5	0.	12.	0.	0.	0.	1.	1.	0.	0.	0.	0.	10.5	10.	32.5	12.5	0.	16.	1.	0.	0.	1.	0.
39	6.	0.	9.	0.	0.5	0.	0.	0.	1.	1.	0.	0.	12.5	9.5	36.	12.5	0.	10.5	1.	0.	0.	0.5	0.
40	6.	0.	0.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	30.	23.5	11.	22.	0.	6.5	0.5	0.	0.	0.	0.
41	12.5	0.	0.	0.	1.5	0.	0.	0.	0.	0.	0.	0.	41.	22.5	3.	11.	0.	8.5	0.	0.	0.	0.	0.
42	12.5	0.	1.	0.	3.	0.	0.	0.	0.	0.	0.	0.	40.	23.	2.	8.5	0.	9.	0.5	0.	0.	0.	0.
43	4.5	1.5	1.5	0.	2.	0.	0.	1.	0.	0.	0.	0.	32.5	21.5	5.	15.	0.	10.5	0.	0.	0.	0.	0.
44	3.5	0.	0.	0.	0.5	0.	0.	0.	0.	0.5	0.	0.	35.	33.5	2.5	17.5	0.	6.	0.	0.	0.5	0.	0.
45	5.5	0.	0.	0.	0.5	0.	0.	0.5	0.	0.	0.	0.	43.	26.5	2.5	16.5	0.	5.	0.	0.	0.	0.	0.
46	13.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	0.	0.	41.	21.	3.	10.5	0.	10.	0.	0.	0.	0.	0.

TABLE I—(Continued)

Percentages of tree pollens—Pinhook bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
47	4.5	0.	0.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	36.	31.5	3.5	18.	0.	3.5	1.	0.	0.	0.	1.5
48	10.5	0.	0.	0.	0.5	0.	0.	0.5	0.	0.	0.	0.	47.5	25.	2.5	7.	0.	6.	0.5	0.	0.	0.	0.
49	7.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	47.5	25.	2.	13.	0.	5.	0.	0.	0.	0.	0.
50	2.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	43.	32.5	2.5	19.	0.	1.	0.	0.	0.	0.	0.
51	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	44.	28.5	4.	17.	0.	1.5	0.	0.	0.	0.	0.
52	6.5	0.	0.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	40.	25.	3.	23.	0.	2.	0.	0.	0.	0.	0.
53	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	42.	33.5	1.5	12.	0.	5.5	0.5	0.	0.	0.	0.
54	8.	0.	0.	0.	0.5	0.	0.	0.5	0.	0.	0.	0.	60.5	20.5	0.5	4.	0.	5.5	0.	0.	0.	0.	0.
55	10.	0.	0.	0.	0.5	0.	0.	0.	0.	0.	0.	0.	44.	26.5	3.5	11.5	0.	4.	0.	0.	0.	0.	0.
56	11.	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	35.5	31.	5.5	14.5	0.	1.5	0.	0.	0.	0.	0.
57	16.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	51.5	21.	3.	6.	0.	2.	0.	0.	0.	0.	0.
58	13.5	0.	0.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	62.	17.5	3.5	3.	0.	0.	0.	0.	0.	0.	0.
59	14.	0.	0.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	54.	25.	1.	3.5	0.	2.	0.	0.	0.	0.	0.

TABLE II

Percentages of tree pollens—Merrillville bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
¼	0.	2.	0.	0.	6.	0.	0.	4.	0.	0.	0.	0.	6.	4.	4.	32.	0.	32.	2.	0.	0.	6.	2.
1	3.	0.	2.	0.	10.	5.	0.	0.	0.	0.	0.	0.	6.	1.	2.	34.	1.	30.	1.	0.	0.	5.	0.
1½	0.5	7.5	1.5	0.	10.5	7.	0.	2.	0.	0.	2.	0.	3.5	1.5	1.5	21.	2.5	33.5	2.	1.	0.5	2.	0.
2	0.	0.	1.	0.	7.	1.	0.	1.	0.	0.	1.	0.	6.	2.	3.	21.	2.	48.	0.	0.	0.	6.	1.
3	0.	2.	0.	0.	12.	1.	0.	0.	0.	0.	0.	0.	4.	2.	2.	39.	4.	30.	2.	1.	0.	0.	1.
4	1.	0.	1.	0.	12.	0.	0.	0.	0.	0.	1.	0.	3.	2.	1.	30.	2.	44.	1.	0.	0.	0.	2.
5	0.	4.	0.	0.	8.	1.3	0.	4.	0.	0.	0.	0.	9.3	1.3	4.	22.6	6.6	28.	5.3	1.3	0.	0.	4.
6	0.	0.	0.8	0.	11.3	0.	0.	0.8	0.	0.	0.	0.	4.3	7.8	2.6	10.4	0.	47.8	4.3	0.	0.	6.	2.6
7	0.	1.	1.	0.	10.	2.	0.	3.	0.	0.	0.	0.	0.	5.	4.	4.	0.	55.	0.	0.	3.	10.	2.
8	1.	3.	1.	0.	20.	2.	0.	1.	0.	0.	0.	0.	0.	2.	3.	4.	0.	50.	2.	0.	1.	7.	3.
9	0.	1.	1.	0.	10.5	3.5	0.5	2.	0.	0.5	1.	0.	8.5	1.5	1.5	6.5	0.	53.	0.5	0.	5.	3.5	0.
10	0.	3.	1.	0.	6.	1.	0.	2.	0.	1.	2.	0.	4.	4.	1.	5.	0.	53.	3.	2.	2.	6.	4.
11	0.5	2.5	0.	0.	11.	0.	0.5	3.5	0.	0.	1.	0.	3.5	0.	1.	1.	0.	66.	3.5	0.	0.	4.	2.
12	0.5	3.5	2.	0.	16.	4.	0.	3.	0.	0.	0.	2.	0.	0.5	1.	3.	1.5	55.	1.5	0.	0.	6.	0.5
13	0.	1.5	1.5	0.	20.	3.	0.	0.5	0.	0.	1.	0.	1.5	2.	0.5	3.	0.	57.5	2.	0.5	0.	1.	0.
14	0.5	3.	2.5	0.	16.5	2.	0.	2.	0.	0.	3 5	0.	2.	2.	0.	0.5	0.	57.5	1.5	0.5	0.	5.5	0.5
15	0.	2.5	3.	0.5	11.	0.	0.	2.5	0.	0.	1.	0.	5.	2.5	2.	10.	0.	48.5	3.5	1.	0.	6.	0.5
16	0.	0.	5.5	0.	16.5	0.	0.	0.5	0.	0.	0.5	0.	0.	5.5	2.	4.	0.	60.5	1.5	0.	0.	3.5	0.
17	0.5	0.5	1.	0.	10.5	0.	0.	1.	0.	0.	0.	0.	1.	23.5	0.5	8.5	0.	48.	9.	0.	0.	5.5	0.

TABLE II—(Continued)

Percentages of tree pollens—Merrillville bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
18	0.	0.	0.5	0.5	9.5	0.	0.	1.	0.	0.	1.	0.5	1.	8.	0.	3.5	0.	60.	10.	0.	0.	4.5	0.
19	0.	0.	3.	0.	7.	0.	0.	0.	0.	0.	0.	0.	3.5	4.5	1.	2.5	0.	71.5	3.	0.	0.	4.	0.
20	0.	1.	0.5	0.	7.	0.	0.	0.	0.	0.	1.	0.	1.5	5.	0.5	5.	0.	70.5	4.	0.	0.	4.	0.
21	0.5	0.	2.5	0.	0.	0.	0.	0.	0.	0.	0.5	1.	6.5	10.	0.5	15.	0.	57.	1.5	1.	0.	2.	0.
21⅛	0.	0.5	3.	0.	4.	0.	0.	0.5	0.	1.	0.	0.	0.5	9.	1.5	4.	0.	69.	4.	0.	0.5	2.5	0.
22	0.	0.	0.5	0.	6.	0.	0.	0.5	0.	0.	0.5	0.5	1.5	5.	0.	1.	0.	72.	6.	1.	0.5	5.	0.
23	2.	0.5	3.	0.5	9.5	0.	0.	0.5	0.	1.	0.	0.5	5.5	11.5	2.5	9.	0.	49.	1.5	0.	0.	3.	0.5
24	9.5	0.	8.5	0.	2.5	0.	0.	1.5	0.5	0.	0.	4.	19.	16.	1.	16.	0.	19.	0.	0.	0.5	1.	1.
25	14.	0.	1.	0.	2.5	0.	0.	0.	0.	3.	0.	0.	46.5	23.	0.5	3.5	0.	6.	0.	0.	0.	0.	0.
26	23.5	5.	1.	0.	0.	0.	0.	0.	0.	2.5	0.	0.	43.	15.5	0.5	5.5	0.	0.	0.	0.	0.	0.5	0.
27	6.5	0.	0.	0.	0.5	0.	0.	0.	0.5	0.5	0.	0.	29.5	43.	2.5	13.	0.	0.	0.	0.	0.	0.5	0.
28	10.5	0.	0.	0.	0.	0.	0.	0.	0.	1.5	0.	0.	35.5	39.5	0.5	12.5	0.	0.	0.	0.	0.	0.	0.
29	3.5	0.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	0.	53.	37.	0.	4.	0.	1.	0.	0.	0.	0.	1.
30	11.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	48.	26.5	0.	11.	0.	3.	0.	0.	0.	0.	0.
31	6.5	0.	1.	0.	0.5	0.	0.	0.	0.	0.	0.	0.	55.5	29.	0.5	3.	0.	4.	0.	0.	0.	0.	0.
32	9.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	65.5	21.	2.	2.	0.	0.	0.	0.	0.	0.	0.
33	7.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	66.5	21.5	2.	2.5	0.	0.	0.	0.	0.	0.	0.
34	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	60.	14.	4.	6.	0.	4.	0.	0.	0.	0.	0.